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(54) **VERTICAL TAKE-OFF AND LANDING AIRCRAFT**

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Related U.S. Application Data

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(51) **Int. Cl.**⁷ **B64C 15/02**

(52) **U.S. Cl.** **244/12.3; 244/12.4; 244/17.23; 244/23 A; 244/23 B**

(58) **Field of Search** **244/6, 12.3, 12.4, 244/17.23, 17.25, 23 A, 23 B**

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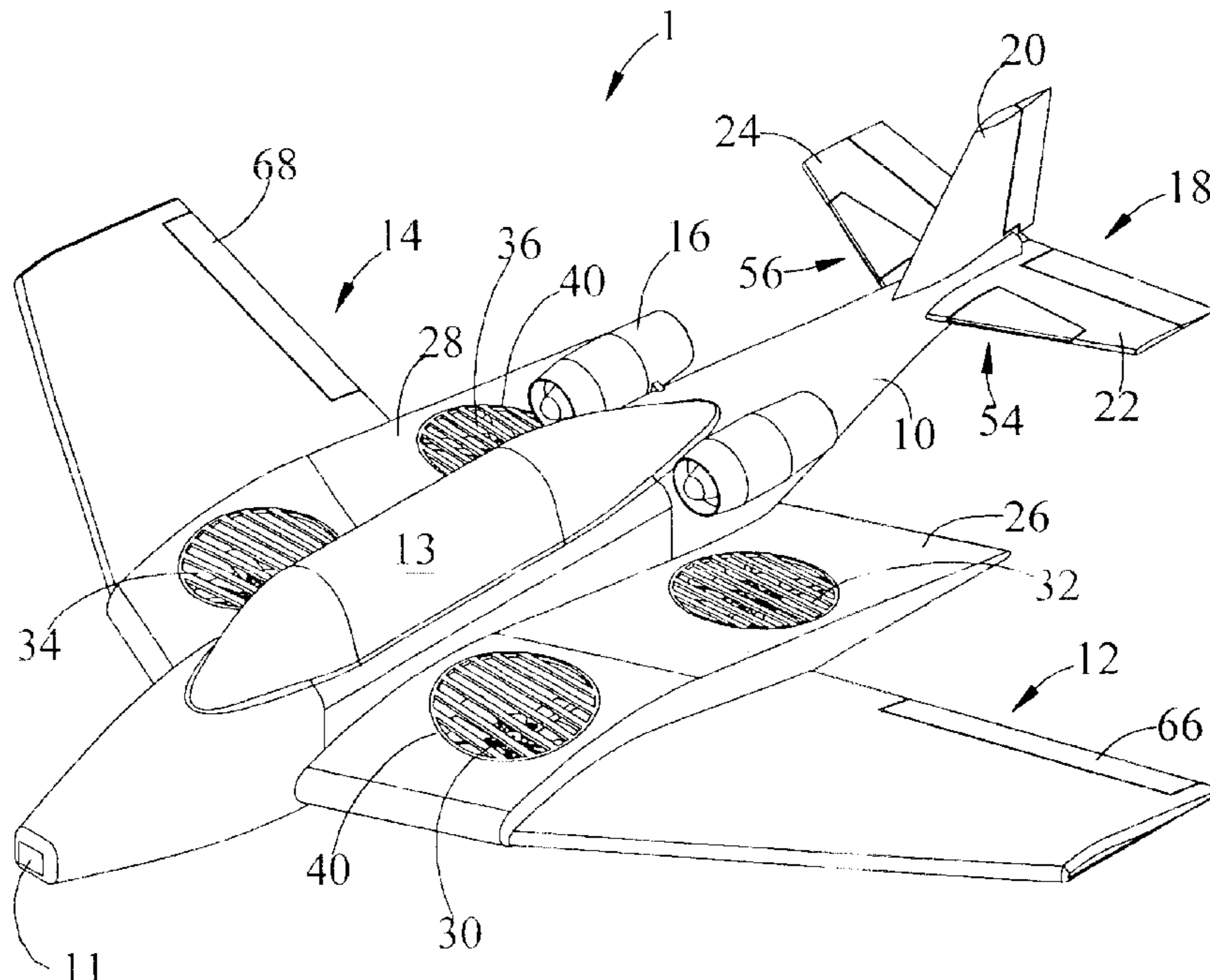
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(57) **ABSTRACT**

A vertical take-off and landing aircraft includes a fuselage, a left wing, a right wing, at least one forward thruster, a horizontal stabilizer and a vertical stabilizer. The left and right wings extend from substantially a middle of the fuselage on left and right sides, respectively. The at least one forward thruster is preferably mounted to the fuselage, substantially behind the left and right wings. The horizontal stabilizer extends from a rear of the fuselage. The vertical stabilizer extends from a top of the fuselage at a rear thereof. At least two left lift rotors are retained in the left wing and at least two right lift rotors are retained in the right wing. A second embodiment of the VTOL aircraft includes a fuselage truncated behind the left and right wings with a twin tail empennage.

23 Claims, 7 Drawing Sheets



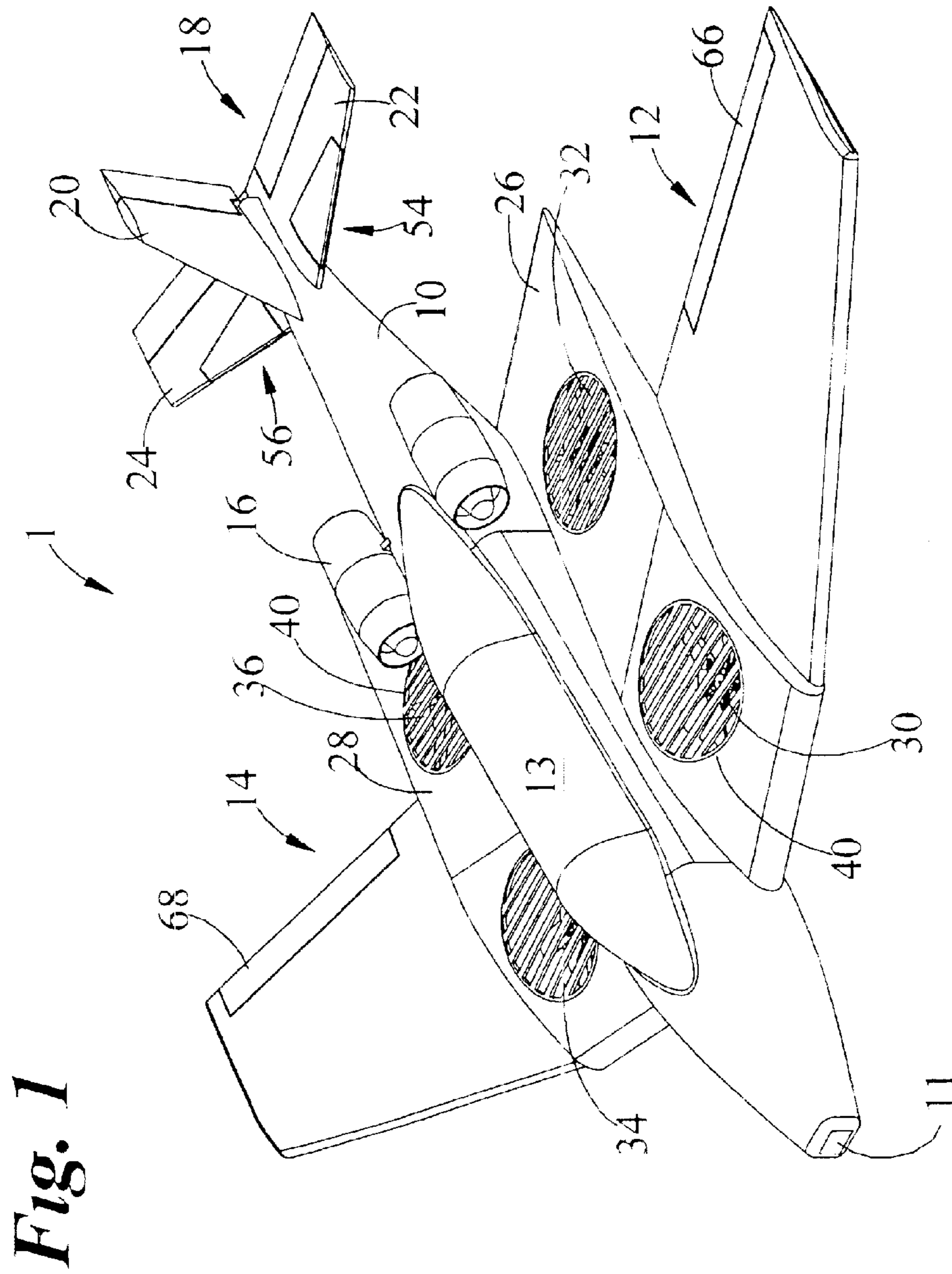


Fig. 2

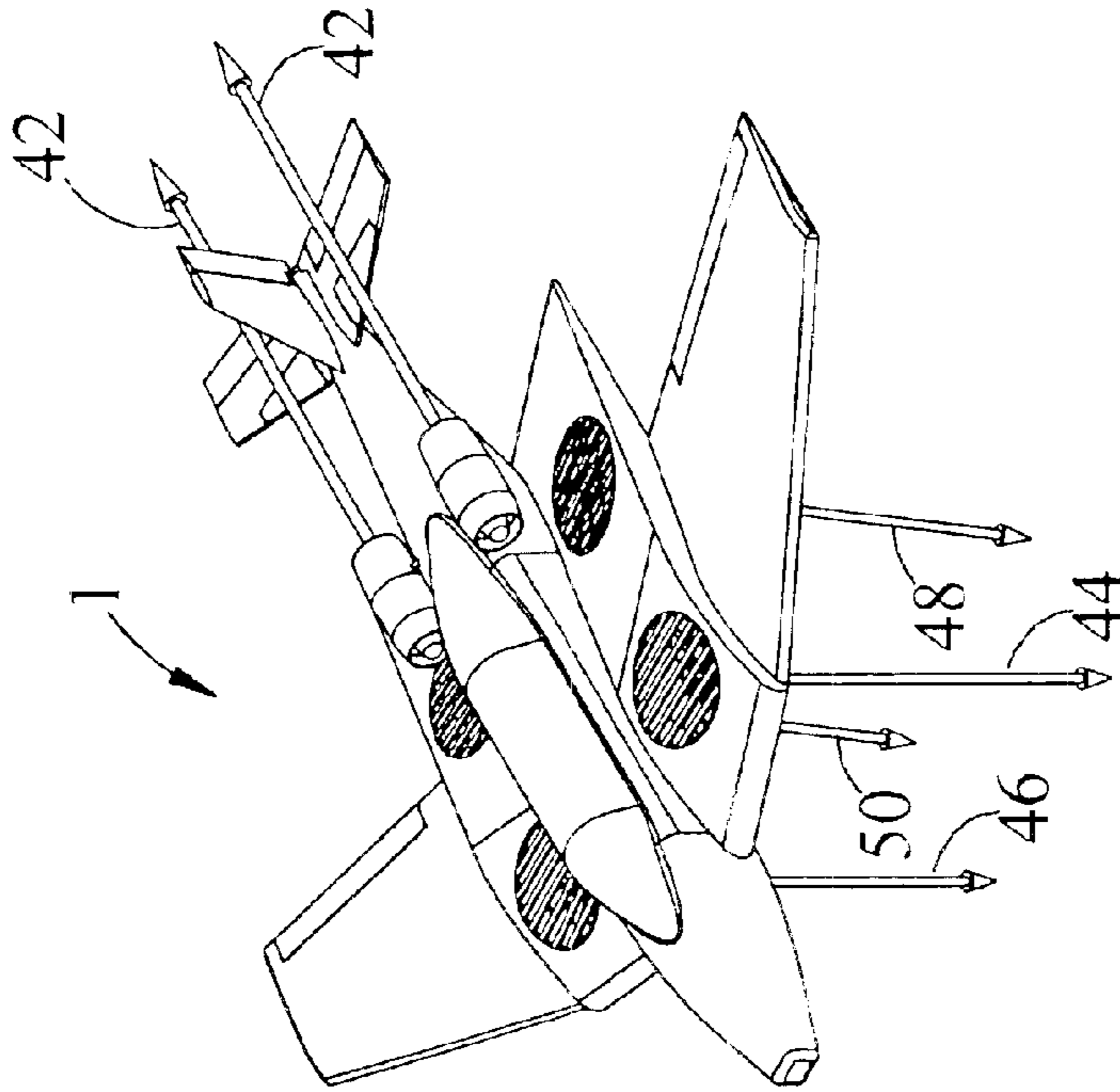


Fig. 2a

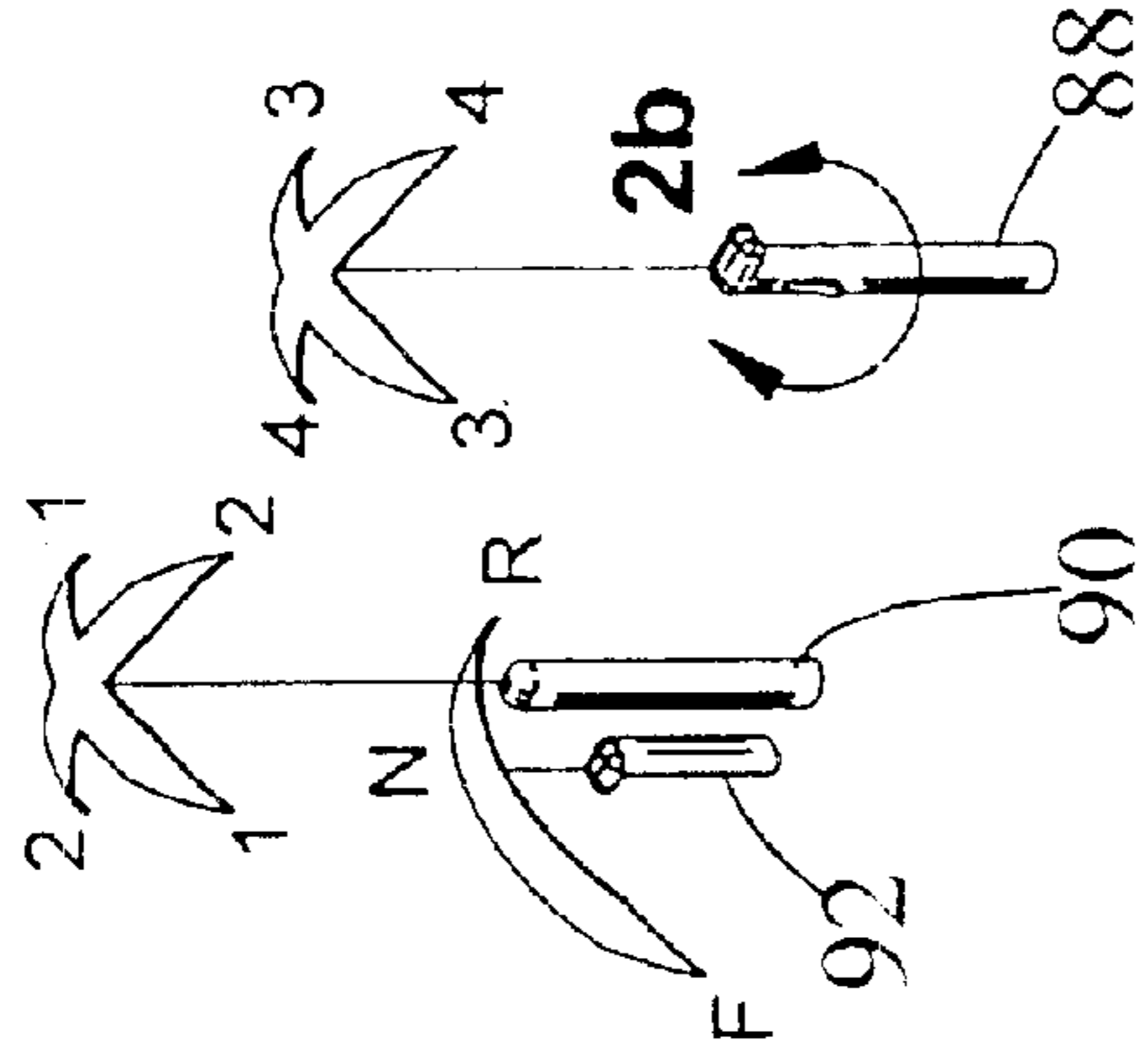
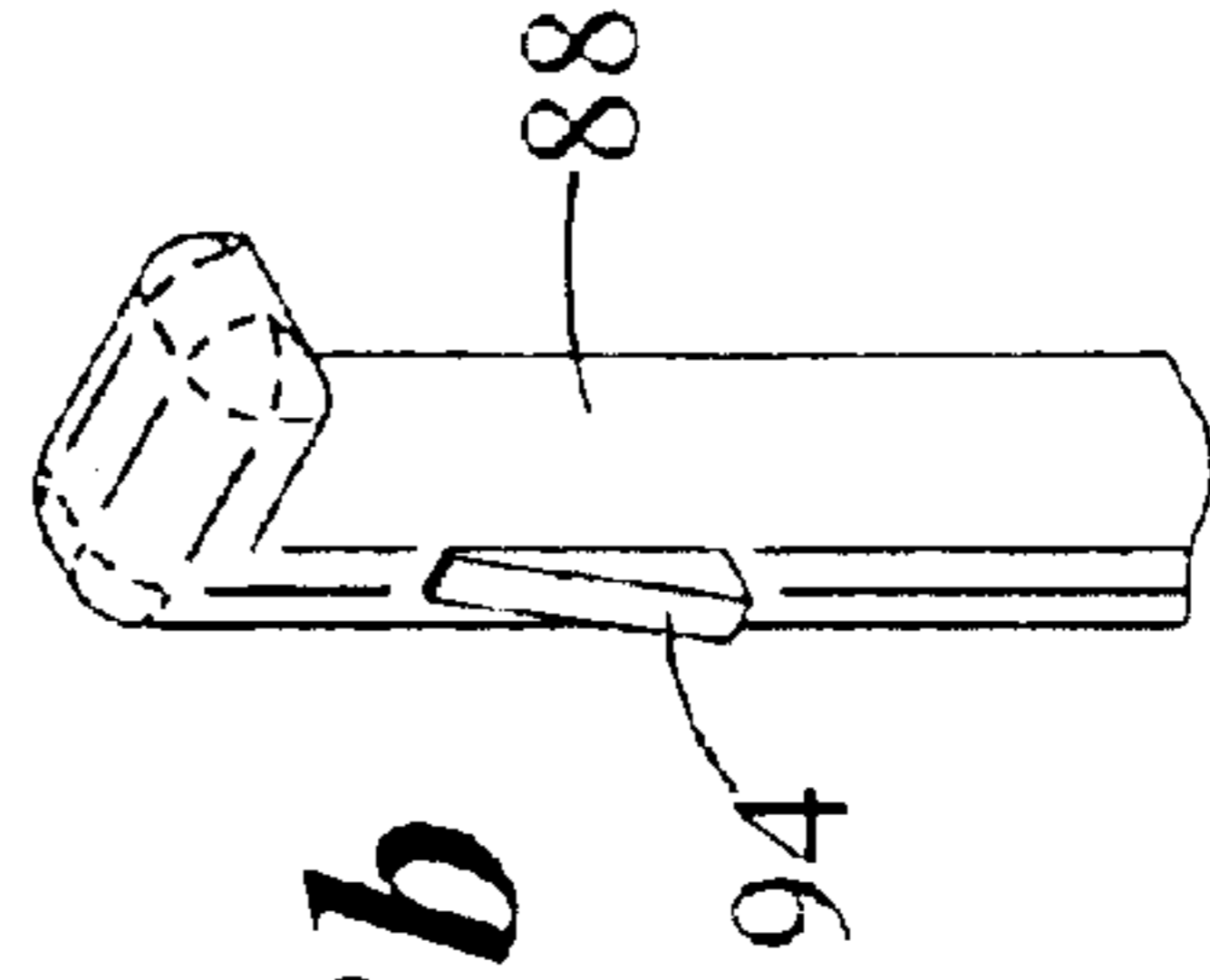
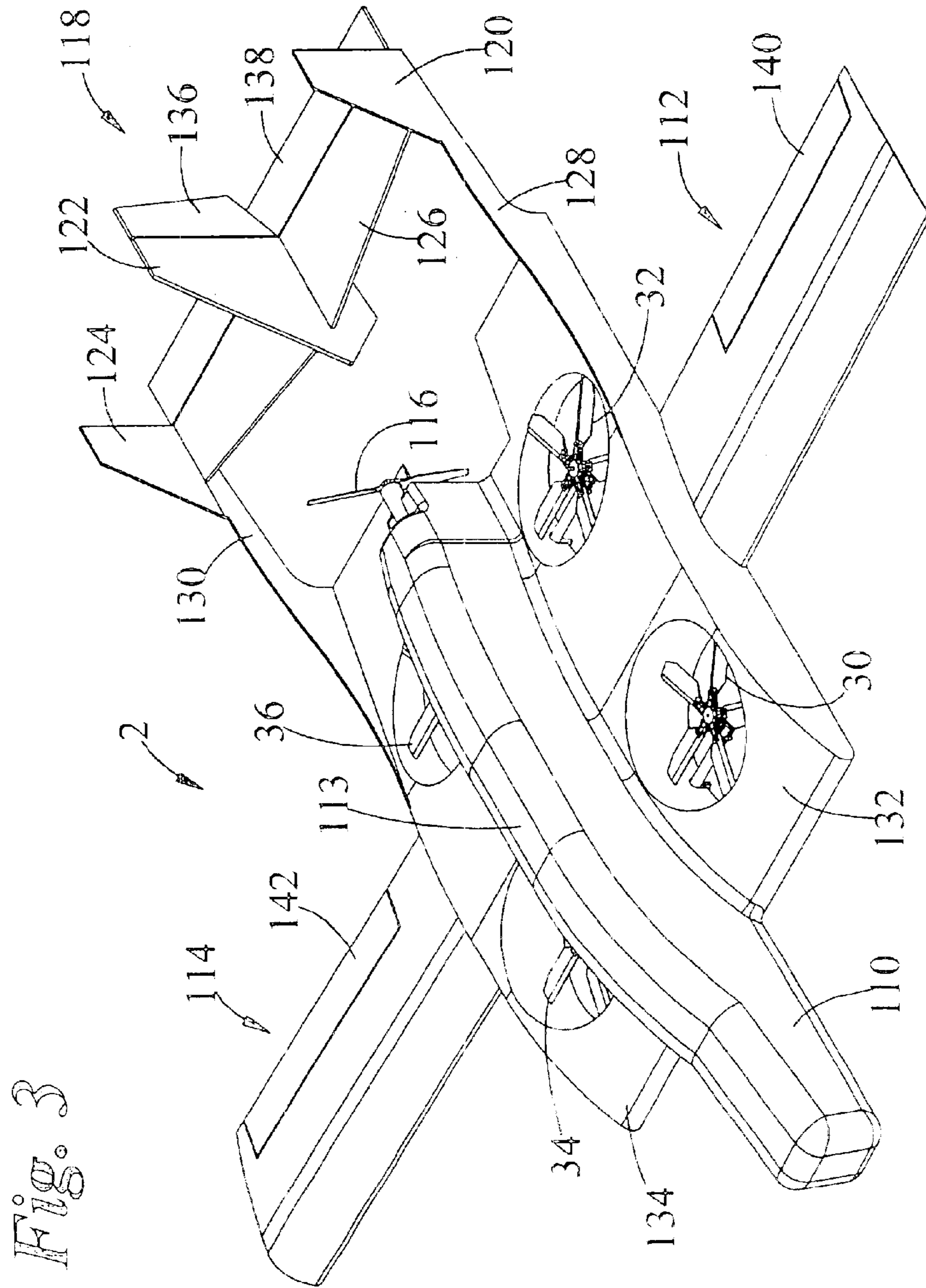


Fig. 2b





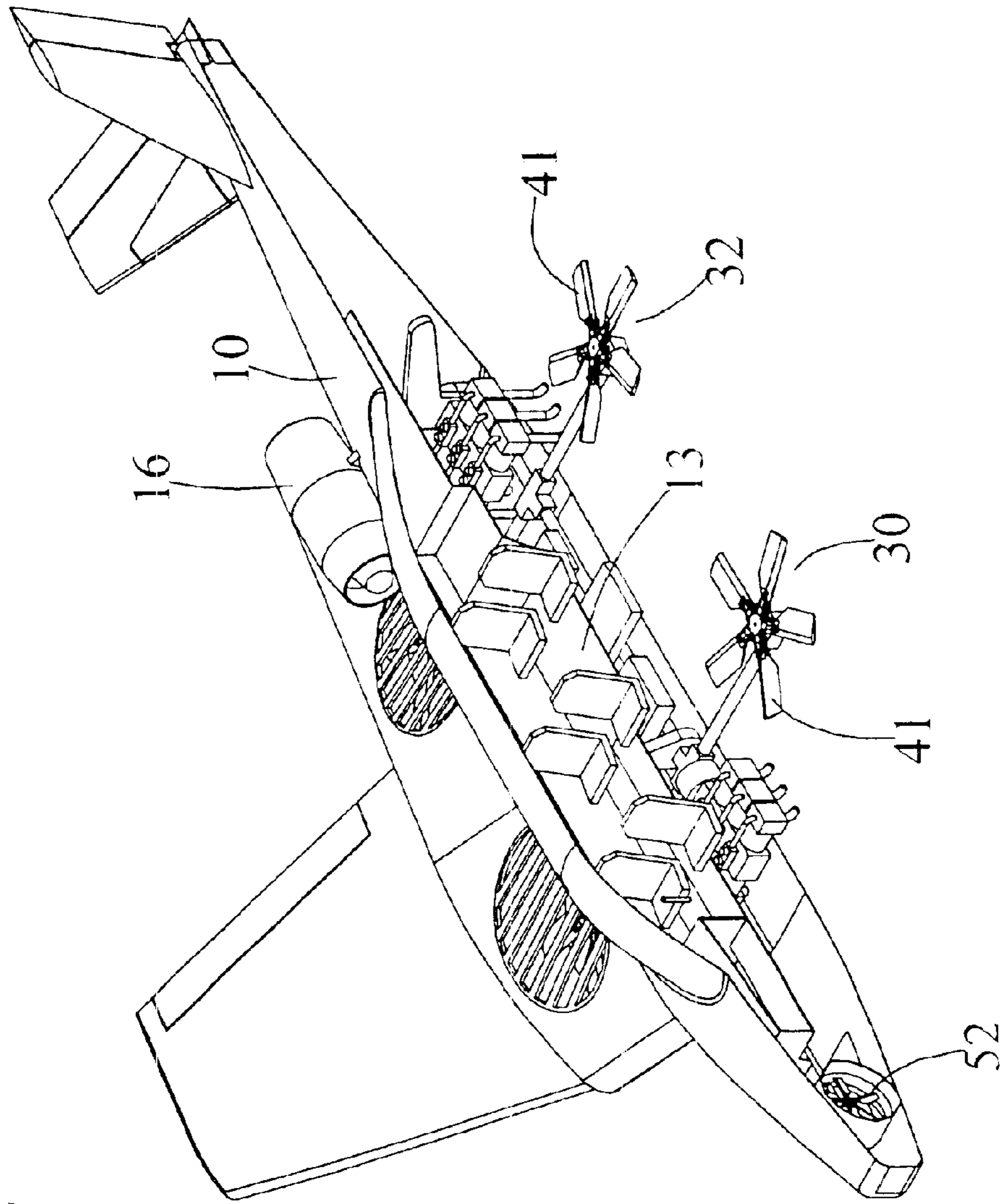


Fig. 4

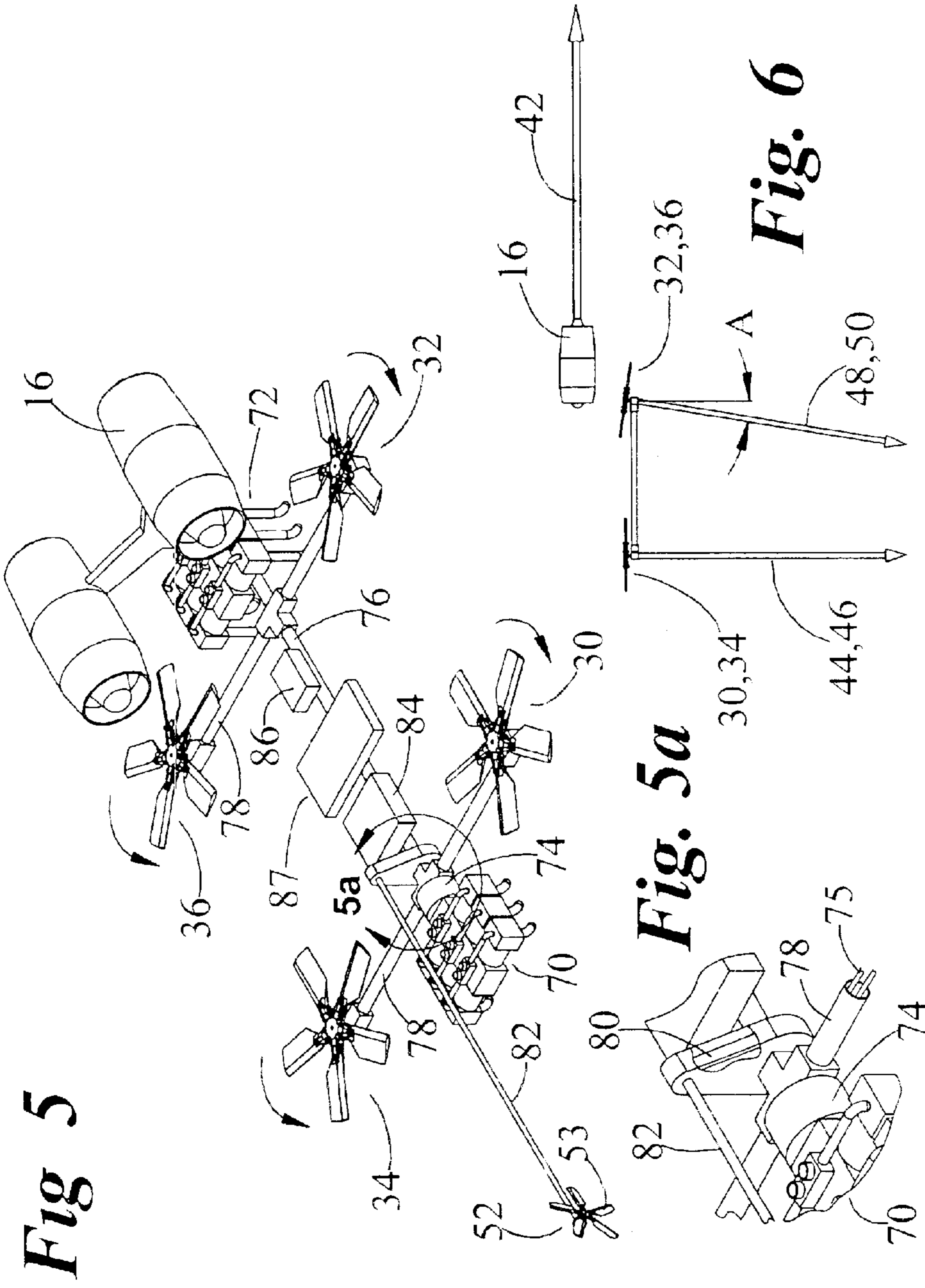
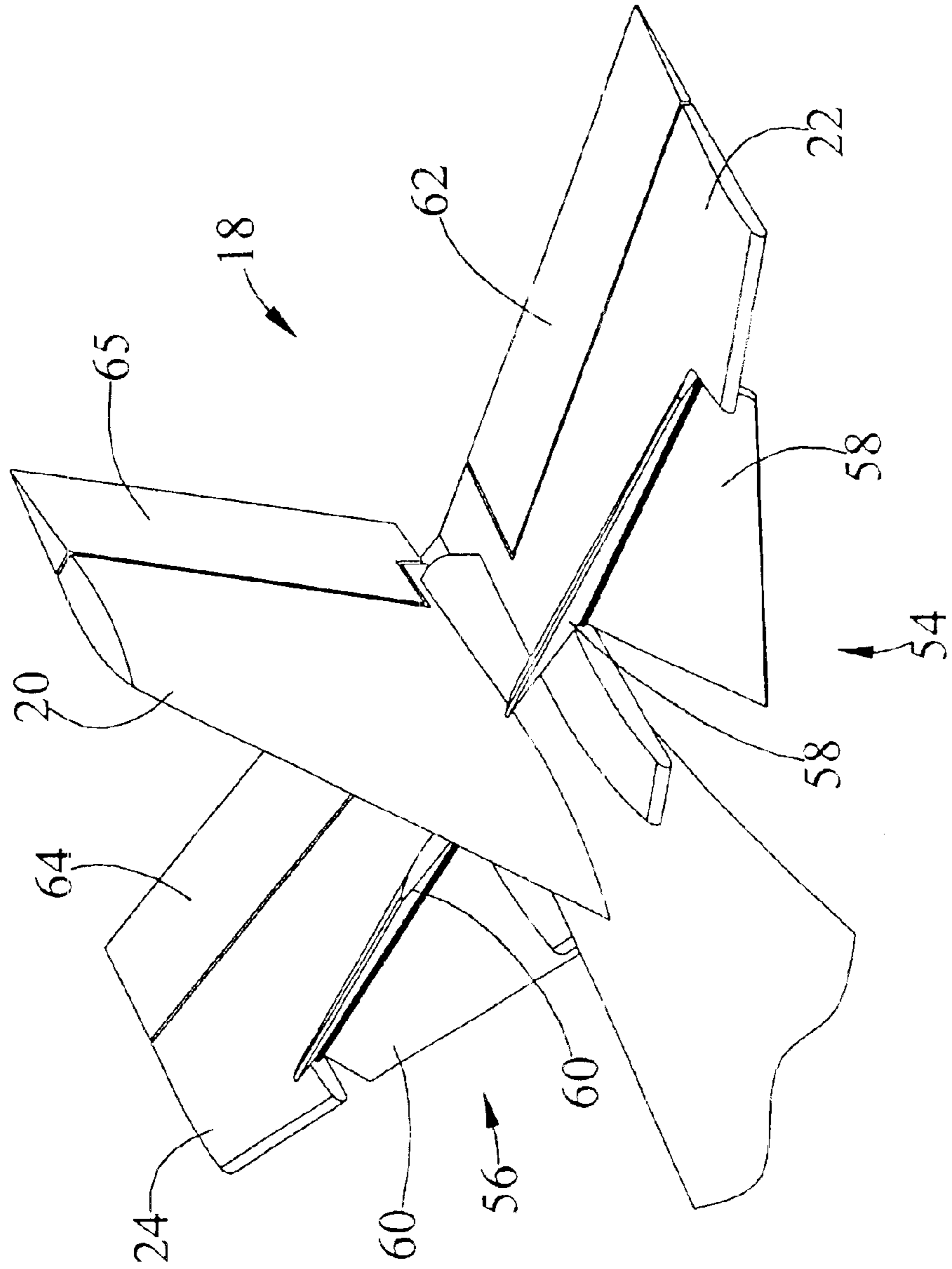


Fig. 5

Fig. 5a

Fig. 6

Fig 7



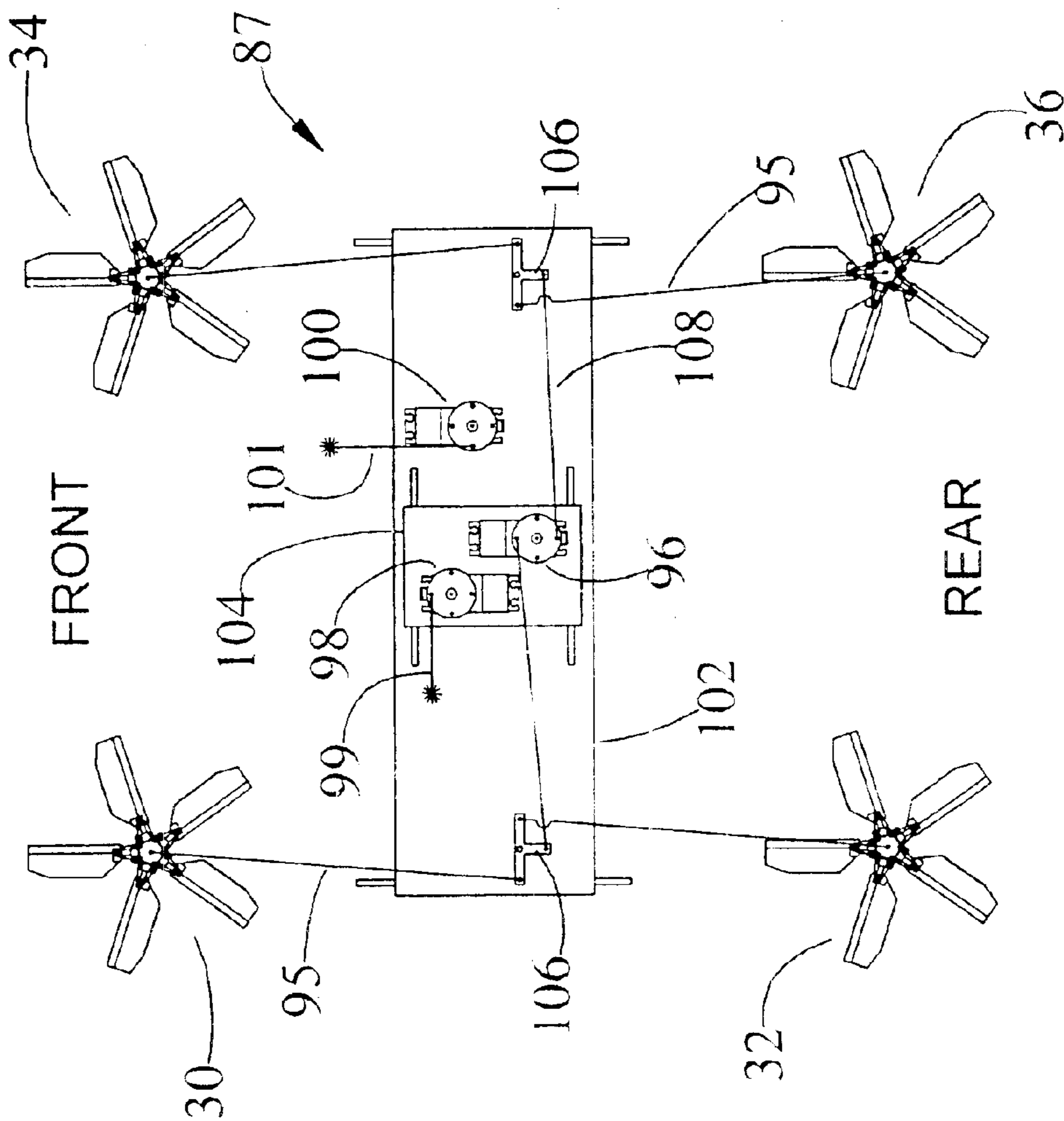


Fig. 8

VERTICAL TAKE-OFF AND LANDING AIRCRAFT

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a utility patent application taking priority from provisional application No. 60/438,429 filed on Jan. 6, 2003.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to aircraft and more specifically to a vertical take-off and landing aircraft, which includes improved stability in hover flight over that of a helicopter.

2. Discussion of the Prior Art

The prior art provides several different types of vertical take-off and landing (VTOL) aircraft. One common VTOL method is that of a tilt-rotor design, where typically two larger propellers are mounted to the ends of an abbreviated wing that is designed to tilt the rotors from a vertical position to a horizontal position for normal flight. A drawback to this design is that there is an inherent "danger zone" of time, while the lift of the aircraft is reduced as its wings/propellers are rotated into the forward flight position. One example of the above challenge is encountered by the U.S. military's "Osprey" aircraft.

Another common VTOL method is known as redirected thrust. Although technically the same in terms of physics, these craft are usually powered by turbofan/jet engines, which produce tremendous amounts of directed thrust, which is then redirected downward for vertical take-off and tilted or redirected rearward to propel the plane into forward flight. The same danger of losing lift is present with the redirected thrust. However, the danger zone is greatly reduced, because of the horsepower to weight ratio. The best example of redirected thrust is the British military's AV8 Harrier fighter jet. The Harrier fighter jet is probably the most successful VTOL aircraft, except for the helicopter. Further, U.S. Pat. No. 5,890,441 to Swinson et al. discloses a horizontal and vertical take-off and landing unmanned aerial vehicle. The invention includes two vertical lift devices equally and longitudinally spaced from the center of gravity of the apparatus.

Accordingly, there is a clearly felt need in the art for a vertical take-off and landing aircraft, which does not have an inherent "danger zone" and provides improved stability in hover flight over that of a helicopter.

SUMMARY OF THE INVENTION

The present invention provides a vertical take-off and landing aircraft, which does not have a "danger zone." The vertical take-off and landing aircraft (VTOL aircraft) includes a fuselage, a left wing, a right wing, at least one forward thruster, a horizontal stabilizer and a vertical stabilizer. The left wing extends from a left side of the fuselage at substantially a middle thereof and the right wing extends from a right side of the fuselage at substantially a middle thereof. The at least one forward thruster is preferably mounted to the fuselage, substantially behind the left and right wings. The horizontal stabilizer includes a left horizontal stabilizer portion and a right horizontal stabilizer portion. The left horizontal stabilizer portion extends from a left side of the fuselage at a rear thereof and the right horizontal stabilizer portion extends from a right side of the fuselage at a rear thereof. The vertical stabilizer extends from a top of the fuselage at a rear thereof.

The left wing includes a lift rotor housing, adjacent the left side of the fuselage and the right wing includes a right rotor housing, adjacent the right side of the fuselage. The left rotor housing contains at two left lift rotors and the right rotor housing contains at two right lift rotors. Each lift rotor has at least four blades that preferably include collective pitch. The angular orientation of the lift blades on each lift rotor is preferably controlled by a central flight computer through autopilot or at least one control stick. The forward flight of the VTOL aircraft is also controlled by the central flight computer. The central flight computer receives input from three gyroscopes. A single gyroscope measures pitch, yaw or roll. Preferably, a nose rotor is located in a nose of the fuselage. A left air brake is disposed at a front of the left horizontal stabilizer portion and a right air brake is disposed at a front of the right horizontal stabilizer portion. A second embodiment of the VTOL aircraft includes a fuselage truncated behind the left and right wings and a twin tail empennage.

Accordingly, it is an object of the present invention to provide a VTOL aircraft, does not have an inherent "danger zone"

Finally, it is another object of the present invention to provide a VTOL aircraft, which has improved hover stability over that of a helicopter.

These and additional objects, advantages, features and benefits of the present invention will become apparent from the following specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a VTOL aircraft in accordance with the present invention.

FIG. 2 is a perspective view of a VTOL aircraft, illustrating the thrust path of the lift rotors and a forward thruster in accordance with the present invention.

FIG. 2a is a perspective view of three flight control sticks of a VTOL aircraft in accordance with the present invention.

FIG. 2b is an enlarged perspective view of a hover control stick of a VTOL aircraft in accordance with the present invention.

FIG. 3 is a perspective view of a second embodiment of a VTOL aircraft in accordance with the present invention.

FIG. 4 is a perspective of a VTOL aircraft with a portion of the fuselage cutaway and the left wing removed in accordance with the present invention.

FIG. 5 is a perspective view of a lift rotor drive system and a thrust drive system of a VTOL aircraft in accordance with the present invention.

FIG. 5a is an enlarged perspective view of a nose rotor drive system of a VTOL aircraft in accordance with the present invention.

FIG. 6 is a schematic drawing of the angular orientation of at least two front lift rotors and at least two rear lift rotors of a VTOL aircraft in accordance with the present invention.

FIG. 7 is an enlarged perspective view of a rear of a fuselage with left and right air brakes in an actuated position of a VTOL aircraft in accordance with the present invention.

FIG. 8 is a schematic drawing of a hover attitude control system of a VTOL aircraft in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to the drawings, and particularly to FIG. 1, there is shown a perspective view of a VTOL aircraft

1. The VTOL aircraft 1 includes a fuselage 10, a left wing 12, a right wing 14, at least one forward thruster 16, a horizontal stabilizer 18 and a vertical stabilizer 20. The left wing 12 extends from a left side of the fuselage 10 at substantially a middle thereof and the right wing 14 extends from a right side of the fuselage 10 at substantially a middle thereof. The at least one forward thruster 16 is preferably mounted to the fuselage 10, substantially behind the left and right wings. The horizontal stabilizer 18 includes a left horizontal stabilizer portion 22 and a right horizontal stabilizer portion 24. The left horizontal stabilizer portion 22 extends from a left side of the fuselage 10 at a rear thereof and the right horizontal stabilizer portion 24 extends from a right side of the fuselage 10 at a rear thereof. The vertical stabilizer 20 extends from a top of the fuselage 10 or the horizontal stabilizer 18 at a rear thereof.

The left wing 12 includes a lift rotor housing 26, adjacent the left side of the fuselage 10 and the right wing 14 includes a right rotor housing 28, adjacent the right side of the fuselage 10. The left rotor housing 26 includes a front left lift rotor 30 and a rear left lift rotor 32. The right rotor housing 28 includes a front right lift rotor 34 and a rear right lift rotor 36. A rotor protector 40 is preferably placed on top of each lift rotor to protect thereof from damage due to objects drawn by each lift rotor and allow support for entering and exiting a cockpit 13. With reference to FIG. 4, each lift rotor has at least four lift blades 41. Each lift rotor preferably includes collective pitch. Collective pitch allows the angular orientation of the at least four lift blades 41 to be changed. The ability to change the angular orientation of each lift rotor allows the VTOL aircraft 1 to hover over uneven terrain. Collective pitch is well known in the art and need not be explained in detail.

The thrust vectors of the at least one forward thruster 16 and the lift rotors are illustrated in FIGS. 2 and 6. A forward thrust vector 42 of each forward thruster 16 points substantially horizontal and to the rear of the fuselage 10. A front left thrust vector 44 of the front left lift rotor 30 points substantially perpendicular to the fuselage 10 and a front right thrust vector 46 of the front right lift rotor 34 points substantially perpendicular to the fuselage 10. A rear left thrust vector 48 of the front left lift rotor 32 points downward at an angle "A" from the yaw axis of the fuselage 10 and a rear right thrust vector 50 of the front right lift rotor 36 points downward at an angle "A" from the yaw axis of the fuselage 10. The value of angle "A" is preferably between 5–15 degrees, but other values may also be used. The angulation of the rear left and right lift rotors offsets the slight forward thrust provided by the at least one forward thruster 16 to prevent the VTOL aircraft 1 from prematurely moving forward during hover flight. The left lift rotors have a directional rotation opposite that of the right lift rotors. The at least one forward thruster 16 is preferably running, even when the VTOL aircraft 1 is hovering over a set location.

Preferably, a nose rotor 52 is located in a nose of the fuselage 10. The nose rotor 52 includes at least four nose blades 53. The at least four nose blades 53 preferably have collective pitch. A left air brake 54 is disposed at a front of the left horizontal stabilizer portion 22 and a right air brake 56 is disposed at a front of the right horizontal stabilizer portion 24. With reference to FIG. 7, the left air brake 54 includes two left brake flaps 58, which spread apart from each other in an open position. The right air brake 56 includes two right brake flaps 60, which spread apart from each other in an open position. The left and right air brakes provide horizontal stopping during forward flight and the ability to move rearward during hover flight.

A left elevator 62 is pivotally retained on a rear of the left horizontal stabilizer portion 22 and a right elevator 64 is pivotally retained on a rear of the right horizontal stabilizer portion 24. A rudder 65 is pivotally retained on a rear of the vertical stabilizer 20. A left aileron 66 is pivotally retained on a rear of the left wing 12 and a right aileron 68 is pivotally retained on a rear of the right wing 12.

A first engine 70 is preferably disposed at substantially a front of the fuselage 10 and a second engine 72 is preferably disposed at substantially a rear of the fuselage 10. With reference to FIG. 5a, the first engine 70 preferably drives the lift rotors through a first clutch 74, a central drive shaft (not shown) and a single rotor drive belt 75 to each lift rotor. The central drive shaft is preferably retained in a central protection tube 76. Each drive belt 75 is preferably retained in a rotor tube 78. The nose rotor 52 is preferably driven by the central drive shaft, a nose drive belt 80, a drive shaft 82 and a set of gears (not shown). If the first engine 70 fails, the first clutch 74 will disengage and a second clutch (not shown) will engage the second engine 72 and the central drive shaft.

The at least one forward thruster 16 may be a propeller, a turbo fan or a jet turbine. If the at least one forward thruster is a propeller or a turbo fan, the second engine 72 is used to drive thereof through an appropriate drive system.

The attitude and movement of the VTOL aircraft 1 is controlled through at least one central flight computer 84 and a gyro sensing unit 86. Preferably, two central flight computers 84 are used. A second central flight computer acts as a redundant backup. The gyro sensing unit 86 includes six gyroscopes. Two gyroscopes are assigned to the roll, pitch or yaw axis. Each second gyroscope acts a redundant backup to the first gyroscope.

With reference to FIG. 2a, the central flight computer 84 will receive input through a hover control stick 88, an attitude control stick 90 and a throttle stick 92. The hover control stick 88 includes a trigger 94. Moving the hover control stick 88 in the 3—3 direction controls the collective pitch of the at least four lift rotors and engine speed of the first engine 70. Pushing the hover control stick 88 forward increases the angular orientation of the at least four lift blades 41 on each lift rotor and increases the engine speed of the first engine with the result of providing increased lift to the VTOL aircraft 1. Pulling the hover control stick 88 rearward decreases the angular orientation of the at least four lift blades 41 on each lift rotor and decreases the engine speed of the first engine with the general result of providing decreased lift to the VTOL aircraft 1.

Moving the hover control stick 88 in the 4—4 direction controls the pivoting of the rudder 65. When the hover control stick 88 is pushed to the right, a nose 11 of the fuselage 10 turns to the right. When the hover control stick 88 is pushed to the left, the nose 11 of the fuselage 10 turns to the left. When the trigger 94 is pulled and the hover control stick 88 is pushed to the right; the angular orientation of the at least four nose blades 53 are changed, such that the VTOL aircraft 1 moves sideways right without affecting roll axis stability. When the trigger 94 is pulled and the hover control stick 88 is pushed to the left; the angular orientation of the at least four nose blades 53 are changed, such that the VTOL aircraft 1 moves sideways left.

Moving the attitude control stick 90 in the 1—1 direction controls the attitude of the VTOL aircraft 1 about the pitch axis. A forward motion of the attitude control stick 90 causes the nose 11 to dive and a back motion of the attitude control stick 90 causes the nose 11 to lift. Moving the attitude control stick 90 in the 2—2 direction controls the attitude of

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the VTOL aircraft **1** about the roll axis. Moving the attitude control stick **90** to the right causes the right wing **14** to be lower than the left wing **12** and moving the attitude control stick **90** to the left causes the left wing **12** to be lower than the right wing **14**.

When the throttle control stick **92** is in the center position (straight-up), the thrust of the second engine **72** is at idle and the left and right air brakes are in a closed position. Moving the throttle control stick **92** forward increases the engine speed of the second engine **72** and/or the thrust of the at least one forward thruster **16**. Moving the throttle control stick **92** rearward from the center position approximately 50% of the maximum rearward movement, preferably starts opening the left and right air brake. The left and right air brakes act as a brake by putting a drag on the forward motion of the VTOL aircraft **1**. When the throttle control stick **92** is pulled rearward to a maximum position, left and right air brakes will fully open and the engine speed or the forward thrust of the at least one forward thruster **16** will be preferably increased to 60–65% of full power. The result of throttle control stick **92** being at a rearward maximum position is that the thrust of the at least one forward thruster **16** will reflect off the left and right air brakes and move the VTOL aircraft **1** rearward, during hover flight.

With reference to FIG. **8**, a hover attitude control system **87** includes at least four actuation rods **95**, a collective pitch servo motor **96**, a roll servo motor **98**, a pitch servo motor **100**, a pitch slide plate **102** and a roll slide plate **104**. The collective pitch of the at least four lift rotors are preferably each controlled by at least one actuation rod **95**. The collective pitch of the nose rotor **52** is preferably controlled by at least one nose actuation rod (not shown). The movement of the at least four actuation rods **95** are preferably controlled by the collective pitch servo motor **96**, the roll servo motor **98** and the pitch servo motor **100**. The pitch slide plate **102** is slidably attached to the fuselage **10** and moves from a front to a rear of the fuselage **10**. The roll slide plate **104** is attached to a top of the pitch slide plate **102** and moves perpendicular to the sliding motion of the pitch slide plate **102**. The collective pitch servo motor **96** actuates a pair of pivot plates **106** through a pair of push rods **108**. The pivot plates **106** control the collective pitch of the at least four lift rotors through at least four actuation rods **95**.

The VTOL aircraft **1** is pivoted along the pitch axis by moving the pitch slide plate **102** with the pitch servo motor **100**, through an actuation rod **101**. The pitch servo motor **100** decreases or increases the collective pitch of the front rotors relative to the rear rotors. The VTOL aircraft **1** is pivoted along the roll axis by moving the roll slide plate **104** with the roll servo motor **98**, through an actuation rod **99**. The roll servo motor **98** decreases or increases the collective pitch of the left side rotors relative to the right side rotors. The collective pitch of the at least four nose blades **53** are preferably controlled through a nose servo motor and the at least one nose actuation rod (neither shown).

The movement of the servo motors are controlled by the at least one central flight computer **84**. The at least one central flight computer **84** operates the servo motors by instruction from the control sticks or by instruction from autopilot.

With reference to FIG. **3**, a second embodiment of the VTOL aircraft **2** includes a fuselage **110**, a left wing **112**, a right wing **114**, at least one forward thruster **116**, and a twin tail empennage **118**. The left wing **112** extends from a left side of the fuselage **110** at substantially a middle thereof and the right wing **114** extends from a right side of the fuselage

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110 at substantially a middle thereof. The at least one forward thruster **116** is preferably mounted to a rear of the fuselage **110**. The left wing **112** includes a left rotor housing **132**, adjacent the left side of the fuselage **110** and the right wing **114** includes a right rotor housing **134**, adjacent the right side of the fuselage **110**. The twin tail empennage **118** includes a left auxiliary vertical stabilizer **120**, a vertical stabilizer **122**, a right auxiliary vertical stabilizer **124**, a horizontal stabilizer **126**, a left tail boom support **128** and a right tail boom support **130**.

The left tail boom support **128** extends rearward from the left rotor housing **132** and the right tail boom support **130** extends rearward from the right rotor housing **134**. The left vertical stabilizer **120** extends upward from a rear of the left tail boom support **128** and the right vertical stabilizer **124** extends upward from a rear of the right tail boom support **130**. The horizontal stabilizer **126** is retained between the left and right tail boom supports. The center vertical stabilizer **122** extends upward from a middle of the horizontal stabilizer **126**. A rudder **136** is pivotally retained on a rear of the vertical stabilizer **122**. An elevator **138** is pivotally retained on a rear of the horizontal stabilizer **126**.

The left rotor housing **132** includes the front left lift rotor **30** and a rear left lift rotor **32**. The right rotor housing **134** includes a front right lift rotor **34** and a rear right lift rotor **36**. The rotor protector **40** (not shown) is preferably placed on top of each lift rotor to protect thereof from damage due to objects drawn by each lift rotor and allow support for entering and exiting a cockpit **113**. The at least four lift rotors preferably operate the same way as in FIG. **5**. The thrust vectors are the same as illustrated in FIGS. **2** and **6**. The nose rotor **52**, and the left and right air brakes are not shown in FIG. **3**, but may be included, if desired. A left aileron **140** is pivotally retained on a rear of the left wing **112** and a right aileron **142** is pivotally retained on a rear of the right wing **114**.

The first engine **70** (not shown) is used to rotate the at least four lift rotors through the same elements as in the VTOL aircraft **1**. If the first engine **70** fails, the second engine (not shown) will drive the at least four lift rotors. The at least one forward thruster **116** may be a propeller, a turbo fan or a jet turbine. If the at least one forward thruster is a propeller or a turbo fan, the second engine **72** is used to drive thereof through an appropriate drive system. The attitude and movement of the VTOL aircraft **2** is controlled the same way as in the VTOL aircraft **1**. The VTOL aircraft **2** includes the same control sticks as in the VTOL aircraft **1**. However, the hover control stick **88** does not include the trigger **94**, unless a nose rotor **52** is installed.

While particular embodiments of the invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. A method of providing a vertical take-off and landing aircraft, comprising the steps of:
 - providing a fuselage;
 - extending a left wing from a left side of said fuselage and extending a right wing from a right side of said fuselage;
 - retaining a first left lift rotor in said left wing, retaining at least one second left lift rotor in said left wing behind said first left lift rotor;

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retaining a first right lift rotor in said right wing, retaining at least one second right lift rotor in said right wing behind said first right lift rotor; and providing at least one forward thruster.

2. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: retaining a horizontal stabilizer at a rear of said aircraft.

3. The method of providing a vertical take-off and landing aircraft of claim 2, further comprising the step of: extending a vertical stabilizer from said horizontal stabilizer.

4. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: rotating at least one of said at least two left lift rotors in a direction opposite that of at least one of said at least two right lift rotors.

5. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: retaining a nose rotor in a nose of said fuselage.

6. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the steps of: retaining a left air brake on a left front of said horizontal stabilizer; and retaining a right air brake on a right front of said horizontal stabilizer.

7. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: providing said at least two left lift rotors and said at least two right lift rotors with collective pitch.

8. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: tilting one of said at least one second left lift rotors to provide some rearward thrust, tilting one of said at least one second right lift rotors to provide some rearward thrust.

9. The method of providing a vertical take-off and landing aircraft of claim 1, further comprising the step of: controlling the attitude of said aircraft while hovering with a central flight computer.

10. A method of providing a vertical take-off and landing aircraft, comprising the steps of: providing a fuselage; extending a left wing from a left side of said fuselage and extending a right wing from a right side of said fuselage; retaining a first left lift rotor in said left wing, retaining at least one second left lift rotor in said left wing behind said first left lift rotor; retaining a first right lift rotor in said right wing, retaining at least one second right lift rotor in said right wing behind said first right lift rotor, providing said at least two left lift rotors and said at least two right lift rotors with collective pitch; and providing at least one forward thruster.

11. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the step of: retaining a horizontal stabilizer at a rear of said aircraft.

12. The method of providing a vertical take-off and landing aircraft of claim 11, further comprising the step of: extending a vertical stabilizer from said horizontal stabilizer.

13. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the step of: rotating at least one of said at least two left lift rotors in a direction opposite that of at least one of said at least two right lift rotors.

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14. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the step of: retaining a nose rotor in a nose of said fuselage.

15. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the steps of: retaining a left air brake on a left front of said horizontal stabilizer; and retaining a right air brake on a right front of said horizontal stabilizer.

16. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the step of: tilting one of said at least one second left lift rotors to provide some rearward thrust, tilting one of said at least one second right lift rotors to provide some rearward thrust.

17. The method of providing a vertical take-off and landing aircraft of claim 10, further comprising the step of: controlling the attitude of said aircraft while hovering with a central flight computer.

18. A method of providing a vertical take-off and landing aircraft, comprising the steps of: providing a fuselage; extending a left wing from a left side of said fuselage and extending a right wing from a right side of said fuselage; retaining at least two left lift rotors adjacent a left side of said fuselage, retaining at least two right lift rotors adjacent to a right side of said fuselage; retaining a first left lift rotor in said left wing, retaining at least one second left lift rotor in said left wing behind said first left lift rotor; retaining a first right lift rotor in said right wing, retaining at least one second right lift rotor in said right wing behind said first right lift rotor; and terminating a rear of said aircraft with a twin tail empennage; and retaining at least one forward thruster at a rear of said fuselage.

19. The method of providing a vertical take-off and landing aircraft of claim 18, further comprising the step of: said twin tail empennage including a horizontal stabilizer and a vertical stabilizer from said horizontal stabilizer.

20. The method of providing a vertical take-off and landing aircraft of claim 18, further comprising the step of: rotating at least one of said at least two left lift rotors in a direction opposite that of at least one of said at least two right lift rotors.

21. The method of providing a vertical take-off and landing aircraft of claim 18, further comprising the step of: providing said at least two left lift rotors and said at least two right lift rotors with collective pitch.

22. The method of providing a vertical take-off and landing aircraft of claim 18, further comprising the step of: tilting one of said at least one second left lift rotors to provide some rearward thrust, tilting one of said at least one second right lift rotors to provide some rearward thrust.

23. The method of providing a vertical take-off and landing aircraft of claim 18, further comprising the step of: controlling the attitude of said aircraft while hovering with a central flight computer.